SUPPLY
OF
PURE SPRING-WATER
TO THE
METROPOLIS.

1850.

~~L5,~~
BC3
10/-

C. Stephens

Priory Place
South Lambeth
London

LONDON (Watford) SPRING WATER COMPANY.
Map
Shewing the Situation of Proposed Works for
SUPPLYING THE CITIES OF
LONDON AND WESTMINSTER
THE
Suburbs and other Places,
WITH
PURE SPRING-WATER.
TOGETHER WITH A
Section from the Wells at Bushey Meadows near Watford to Oxford Street, through the Stanmore Heath & Childs Hill Reservoirs, and the Line of Main Pipes.
Reference.
The Proposed Works Colored Red
The Height above Trinity High Water Mark, on Plan is shewn thus 78
Scales.
HORIZONTAL.
2 Miles
VERTICAL.
500 Feet
Printed from Stone by C. F. Cheffins Southampton Buildings Holborn
1850.
F. C. Homersham
ENGINEER
WATFORD
BUSHEY MEADOWS
PUMPING ENGINE
LINE OF PIPES
HIGH SERVICE RESERVOIR
RESERVOIR
CHIPPING BARNET
STANMORE
HARROW ON THE HILL
CHILDS HILL
RESERVOIRS
HAMPSTEAD
HIGHGATE
KILBURN
HAMMERSMITH
BRENTFORD
KEW
MORTLAKE
BARNES
FULHAM
PUTNEY
WANDSWORTH
BATTERSEA
CLAPHAM
EALING
ACTON
HORNSEY
FINCHLEY
HENDON
STANMORE HEATH RESERVOIR.
ELSTREE RESERVOIR.
HARROW RESERVOIR
HAMPSTEAD RESERVOIRS.
CHILDS HILL RESERVOIR
Level of High Service Reservoir.
LINE OF PIPES
PROPOSED WELL
Trinity High Water Mark.

LONDON (WATFORD)

SPRING-WATER COMPANY.

REPORT

TO THE DIRECTORS.

BY S. C. HOMERSHAM, ESQ., C.E.

THIRD EDITION.

London:

JOHN WEALE, ARCHITECTURAL LIBRARY,

59, HIGH HOLBORN.

1850.

J. P. ATKINSON, PRINTER, 20, MURRAY STREET, NEW NORTH ROAD.

REPORT.

To the Directors of the London (Watford) Spring-Water Company.

Gentlemen,

The conviction that a *purer*, a *further*, and a *cheaper* supply of water, distributed in the most approved manner for domestic consumption, is demanded by the urgent necessities of a large portion of the inhabitants of this great metropolis and its suburbs, combined with the belief that these objects may be attained by judicious arrangements for procuring and distributing the spring-water which abounds in the chalk formation near Watford, having induced you to honour me with your commands, to prepare and deposit the plans necessary to enable an application to be made, in the ensuing session, for parliamentary powers to carry out your views, I beg to submit the following Report, which treats—First; On the source from which it is proposed to procure the water, and the quantity which may be obtained. Secondly; On the

quality of this water, and its adaptation for domestic and manufacturing uses. THIRDLY; On the means proposed to distribute this water, and the districts to be furnished with it. And, FOURTHLY; On the cost of carrying out the undertaking, the annual expenses for working, and the income to be derived.

First.

ON THE SOURCE FROM WHICH IT IS PROPOSED TO PROCURE THE WATER, AND THE QUANTITY WHICH MAY BE OBTAINED.

The Bushey Meadows are situated in the valley of the Colne, about three-quarters of a mile north-east of Watford, and are surrounded on the north, north-west, west, and south-west, by almost bare chalk hills varying from 500 to 900 feet in altitude:* the chalk formation in connection with these hills appears at a short distance below the ground at Bushey Meadows, and here, as well as at many other points along the valley of the Colne, are found at a depth varying from 100 to 200 feet beneath the surface, large faults, fissures, or cavities, varying from 12 inches to 12 feet in depth; in boring through the chalk, the approach to these fissures is indicated by the hardness of the chalk, which for a short distance before reaching them is like a rock: when this is penetrated, the chisel suddenly descends into

* See Geological Map, at end of book.

a cavity charged with water, and such water rapidly ascends to within a few inches of the surface, although the ground itself is 169 feet above Trinity high-water mark.*

There can be no doubt this water is derived from the absorption and percolation of the rain which falls upon the hills before described, for it is a characteristic of the chalk formation, when slightly covered with a porous soil, that the heaviest rains, falling upon the sides of the steepest hills, are rapidly absorbed, and large areas of land of this formation, of basin-like forms, are never flooded even in the lowest parts, so rapidly does the greatest fall disappear from the surface.†

A portion of this water is consumed by evaporation, and in supporting vegetation; another portion percolating through the surface, is absorbed and gradually gravitates, until, upheld by the density or impervious character of particular beds of chalk, it accumulates in the interstices which abound in various directions, and being conducted by the inclination of these beds, and the direction of such interstices, is found oozing from the sides of hills, or the bottoms of valleys, in the form of springs, which uniting together, with the surface drainage, produce streams or rivers. Such springs issuing from the chalk formation are often of a powerful character, and discharge large quantities of water. The springs of Amwell and Chadwell, near Ware, in Hertfordshire, which afford a partial supply to the New River Company, are of this origin.

* See Appendix H, page 39. † See Appendices G, page 38, and Q, page 54.

Another, and by far the greatest portion of the rain which falls upon the chalk formation, encountering no such impervious beds, continues to descend through various fissures, until, arrested by the bed of gault clay lying beneath the chalk, it fills the lower cavities and accumulates to such a height as to force its way through subterraneous passages communicating with the sea; in this manner an enormous amount of water is discharged through the shingle or sand which covers the coast, and even into the bed of the sea itself.*

The area of land sloping towards Watford, and consisting for the most part of steep chalk hills, embraces more than 1200 square miles, and calculating that only a depth of 20 inches of rain per annum falls in this locality,† at least one-half, or 10 inches, may be considered as reaching the lower fissures; and that this last amount is *underrated*, there can be no doubt, when it is remembered that here the yields of the rivers and springs only account for a small consumption of the depth of rain falling, and that the rapidity with which water is absorbed by the chalk formation prevents any large amount being carried off by evaporation. This depth of 10 inches of rain per annum, percolating through a surface of 1200 square miles, is equal to supply the immense quantity of *four hundred and eight millions of gallons per day, for every day in the year*, which at present finds a vent and is discharged along the coast.

* See Appendices N, page 49, and F, page 37. † See Appendix T, page 57.

It is proposed to sink a well, or wells, and to drive adits into, the chalk formation under Bushey Meadows, for the purpose of intercepting and tapping the fissures above described; and that a much larger quantity of water than will be required for your undertaking (namely eight millions of gallons per day), *may with facility be procured in this manner from a very small area,** there can be no doubt, from the fact, that a well sunk at Bushey Meadows, in 1840, by order of a Committee of the House of Lords, only 12 feet 6 inches diameter at the bottom, and 34 feet deep, with 4 small bore-holes, 5 inches diameter, and 130 feet below the surface of the ground, was found to supply 1,800,000 gallons per day. An experiment with this well was made in 1840 under the direction of Mr. Robert Stephenson, who reported that when the water was lowered 26 feet by pumping, "it rose with a velocity equal to 2·02 feet "per second, thus yielding 174,500 cubic feet or "1,091,000 gallons per 24 hours." It must be remembered that this was the velocity with which the water regained its original level (a few inches below the surface of the ground); the quantity yielded when the water was 24 feet below the surface, was much more than the above amount, being equal to 1,800,000 gallons as before stated.

In 1840 and 1841, Mr. Robert Stephenson in two reports to the directors of a company, then projected under the title of "The London and Westminster Water Company," recommended the source just described as the most eligible one for procuring

* See Appendix O, page 53.

a supply of pure water, for the use of the metropolis: and *since* these able reports were circulated, some large manufacturers having mills upon the river Colne, and other streams in the locality, have bored holes into the chalk and intercepted the fissures before described, from which they procure a considerable amount of spring-water for manufacturing purposes. One extensive mill-owner and paper manufacturer, at each of four different mills, has sunk a small bore-hole, 8 inches diameter, into the chalk fissures, and derives from them a supply always pellucid, and never failing, equal to nearly two millions of gallons per day.

The New River Company, also, taking a lesson from the valuable information contained in Mr. Stephenson's reports, has sunk wells into the chalk formation at Amwell and Chadwell, and in seasons when "the yields of the several ancient sources of "the New River are unequal to the demand in London, the additional supply is derived from what are "usually termed Artesian wells, sunk in the chalk, "and situated at or near Chadwell, and Amwell, in "Hertfordshire." *

When such practical facts are found to corroborate the deductions of scientific reasoning, it is impossible to doubt that from the deep springs of the chalk formation an enormous amount of water can be easily and cheaply obtained.†

Leaving then this part of the subject, let us inquire,

* Extract of a letter from Mr. W. C. Mylne, engineer of the New River Company, published in *The Times* newspaper, Sept. 21st, 1849.

† See Appendix K, page 46.

Secondly,

WHAT IS THE QUALITY OF THIS WATER, AND ITS ADAPTATION FOR DOMESTIC AND MANUFACTURING USES?

In proposing to supply water for the general and domestic consumption of a population, it is of the greatest importance that such water *should be free from organic matter*, and fit for drinking, culinary, and detergent purposes.*

The water procured from the source before described, is shewn by chemical analysis to be free from one of the principal impurities of all rivers deriving their supplies from the drainage of cultivated ground,† namely, a large quantity of organic matter.‡ Organic matter is present in river-water to a much greater extent in warm, summer, and autumn weather, than at any other period of the year; and it is mainly owing to this circumstance that the Thames water, at such times, is found to abound with the insects so well known to the inhabitants of the metropolis. The small extent to which organic matter can be separated by filtration, is shewn by a report, dated November 8th, 1849, on the water supplied to the inhabitants of Hull, by ARTHUR AIKIN, Esq., F.G.S., and ALFRED SWAINE TAYLOR, M.D., F.R.S., Professors of Chemistry in Guy's

* See Appendix A, page 23. † See Appendix U, page 58.
‡ See Appendix S, page 55.

Hospital. These gentlemen report that Hull water, unfiltered, contains 3·2 grains of organic matter per gallon; and the same water, filtered, 3·0 grains; thus proving that only the small amount of one-fifth of a grain, or the sixteenth part of the whole amount, was separated by this process.* Vegetating matter is described by Professor CLARK as "an "injurious impurity of the water supplied to the "metropolis by the companies." He adds, "Such "impurity renders their waters inferior to the spring-"waters; it imparts an offensive taste; it affords "nourishment to water insects, and encourages their "propagation."†

A specimen of water collected from one of the borings in the valley of the Colne, was submitted in September, 1849, to GEORGE NEWPORT, Esq., F.R.S., and Dr. RONALDS, Lecturer on Chemistry, at the Middlesex Hospital; these gentlemen reported that this water contained less than three-fourths of a grain of organic matter per gallon, and the analysis of other specimens submitted to Professor CLARK, of Aberdeen, also proves its remarkable freedom from organic impurity.‡ In fact, as shewn by Professor CLARK's report, this water may be considered free from organic matter, and as containing little else in combination with it than bi-carbonate of lime. When first raised from the springs, it is 17½ degrees of hardness by Professor CLARK's test; but when exposed in reservoirs for eleven or twelve days, it parts

* See Appendix D, page 31.

† Pamphlet by Professor CLARK, published by Richard and John Taylor, Red Lion Court, Fleet Street, 1849, page 11.

‡ See Appendix I, page 43.

with a portion of the carbonic acid, which enables it to hold lime in solution, and falls to 14 or 15 degrees of hardness, thus becoming as soft, or softer, than the average water supplied to London by the present companies.*

My connection some years since with the Brighton Water Company, which procures its supply from wells sunk, and adits driven into the chalk formation, first drew my attention to the circumstance that water procured from chalk, loses a portion of its carbonic acid and lime by standing in deep reservoirs, and experiments conducted upon the water procured from the springs near Watford, give the same result. In a report by Mr. James Simpson and Mr. James Newlands, dated April, 1849, on the supply of water to Liverpool, it is stated, "that Professor Brande lately analysed the "water supplied by several of the London companies, "and also samples taken direct from the Thames, at "different points, one of these being seventy miles up "the river, near Henley; the quality of these samples "varied from 14 to 17 degrees by Dr. Clark's test, "and contained 19·5 to 23 grains of solid matter per "gallon."† It thus appears that the water from the chalk formation at Watford, is not only free from organic impurity, but also, when supplied from the large reservoirs which it is proposed to construct (as hereafter explained), will be quite as soft, or softer, and better adapted for detergent and manufacturing purposes, than any water at present supplied to the inhabitants of London.

* See Appendices C, page 30, and I, page 43. † See Appendix M, page 48.

This water is reported upon by Professor CLARK, as peculiarly fitted to undergo the softening process invented and patented by him,* and if upon a full consideration of the subject it should be desirable to adopt this process, the form of the ground at Bushey Meadows offers great facilities for constructing the necessary reservoirs and works.

The water procured from chalk springs is at all times perfectly pellucid or clear. Mr. STEPHENSON in his report on the water procured from the experimental well at Bushey Meadows, states, "it may be "considered as entirely divested of any impurities "held in mechanical suspension, of which, indeed, "there wa abundant ocular demonstration, as it was "so beautifully transparent as to admit of the bottom "of the well being seen when it was upwards of thir-"ty feet deep." The Thames water, on the contrary, *at whatever point it may be collected,* becomes foul and muddy after every passing shower; and especially in the spring, when the blossoms fall, and in autumn, when vegetable bodies decay, is impregnated with organic matter, besides being subject to further contamination from unavoidably becoming the common sewer of a large and increasing population, situated upon its water-shed.†

When it is remembered, that the Thames rapidly diminishes in volume above London, and that the gradual introduction of a more complete system of drainage for agricultural purposes has tended of late years to bring the rain off retentive soils in floods, almost as rapidly as it falls, and considerably to di-

* See Appendix I, page 43. † See Appendix R, page 54.

minish the dry-weather yield of the stream, it will be evident that any further subtraction from its volume above London at such seasons, would injuriously affect the interest of many mill-owners and manufacturers, besides seriously obstructing the navigation of the river. These circumstances alone, would render it desirable that the natural reservoirs of water lying in the deep springs of the chalk formation, and subject to none of the many contaminations just mentioned, and injuriously affecting in its collection no one interest, should be made available to supply the population of London, and become adjuncts to the surface springs of Amwell and Chadwell, which, emanating from the same source, have for more than two centuries and a quarter been conducted to the metropolis, and

> "Which thousands drink, who never dream
> "Whence flows the boon they bless."

The foregoing will shew that the amount of water which can be procured from the proposed source is ample, and the quality excellent.

Let us therefore enter,

Thirdly,

ON THE MEANS PROPOSED TO DISTRIBUTE THIS WATER, AND THE DISTRICTS TO BE FURNISHED WITH IT.

The Bushey Meadows, near Watford, in which it is proposed to sink the wells, are situated in a north-

westerly direction, about fourteen miles from Cumberland gate, Hyde Park. Between these points, distant about three miles from Bushey Meadows, is a ridge of ground, varying from four to five hundred feet in elevation; on Stanmore Heath, which forms part of this ridge, it is proposed to construct two reservoirs of an average depth of 27 feet, and capable of containing collectively 70 millions of gallons.

The bottoms of these reservoirs are elevated 390 feet above Trinity high-water mark, and the water collected at Bushey Meadows will be lifted into them through cast-iron pipes, by means of steam pumping engines.

The surface of the water in the well at Bushey Meadows when lowered to its greatest depth by pumping, will stand 136 feet above the same datum. The lift to the bottom of the reservoirs at Stanmore will therefore only amount to 254 feet, by which the elevation is attained of 390 feet above London.

It is intended to conduct water from these reservoirs through a line of cast-iron pipes (laid for the most part in the turnpike road) to another reservoir, situated at Child's Hill, near Hampstead, and distant about three and a half miles from Cumberland Gate, Hyde Park, the bottom of which will be 302 feet above Trinity high-water mark.

This reservoir will hold 24 millions of gallons, and from it a large pipe laid in the Finchley Road will convey water to Oxford Street, or in any other convenient direction to London or Westminster, to

be distributed upon the approved principle of continuous supply.* The elevation of the reservoir at Child's Hill, commands a district at least 110 feet in altitude, above the reach of any existing company. This is an important and populous district, rapidly increasing with houses of the first class, to which an ample supply of pure water, distributed at a cheap rate, would be a great boon. This elevation also gives sufficient pressure in the pipes to admit of lower districts being economically and efficiently supplied through small distributing pipes; a matter of considerable commercial importance.

The whole of the district through which the main pipe passes, from Stanmore Heath to Child's Hill, consists of London clay, and the inhabitants being greatly in need of water, it is proposed to take powers to supply the town of Edgware and all the districts lying within a convenient distance east and west of the line of main pipe, and situated below the principal reservoirs at Stanmore, thus enabling this also large and rapidly increasing population to be supplied with water, which at present mainly depend upon that furnished by carts and butts.

For the convenience of a further large and increasing population, located considerably *above* the principal reservoirs at Stanmore, residing at Hampstead, Elstree, Highwood Hill, Totteridge, Harrow-on-the-hill, Stanmore, etc., it is proposed to construct a high-service reservoir at Stanmore, the bottom of which l be 490 feet high; from this reservoir, water will be conveyed at

* See Appendix E, page 33.

suitable times, through the leading mains, and branch pipes, to service reservoirs, situated at Hampstead, Elstree, and Harrow-on-the-hill: all of these places may thus be constantly furnished (through service pipes) with pure soft spring-water.

The reservoir at Elstree being situated at the highest point of an extensive range of country, will enable it to command a district which greatly needs such supply.

The high-service reservoir at Stanmore will also command Clay Hill, and serve the inhabitants of Bushey and Watford.

From the foregoing it will be seen, that the pipes or conduits intended for conveying the water to the metropolis, will pass through, and can be made subservient to benefit, an important district of upland country, at present beyond the range of any water company, and greatly requiring this accommodation.

It appears, then, that an ample quantity of excellent water may be easily collected and distributed to a numerous population much in want of it.*

The inquiry now remains—

* See Appendix L, page 47.

Fourthly,

WHAT IS THE COST OF CARRYING OUT THE UNDERTAKING, THE ANNUAL EXPENSES FOR WORKING, AND THE INCOME TO BE DERIVED?

Upon examining the accompanying map with the description before given, it will be seen that no serious difficulties of any kind have to be encountered in carrying out the proposed works, the whole being of a simple character.*

By far the greatest portion of the outlay will consist in procuring and laying cast-iron pipes, which, at the present price of iron and labour, may be accomplished at a moderate price.

After a careful investigation, I estimate the cost of the works requisite to collect, raise, and distribute eight millions of gallons of water per day, in London and Westminster, and other places situated below the principal reservoir at Stanmore, but exclusive of parliamentary expenses, at £340,000.

The natures of the works are such as to render this estimate a matter of great certainty, and there can be no difficulty in getting them executed at the amount named.

Eight millions of gallons per day would supply 40,000 houses each with 170 gallons daily, and leave 1,200,000 gallons for wholesale consumers.

* See Map, beginning of book.

The expense for coals, labour, taxes, collection of rates, and management, when the whole of the eight millions of gallons are supplied, may be taken at £15,725 per annum.

THE ANNUAL INCOME AND EXPENDITURE WILL THEN STAND THUS:—

INCOME.

Say 40,000 houses, supplied with 170 gallons per day, at an average rental of 20s. per house .	£40,000	0	0
1,200,000 gallons distributed to wholesale consumers, at 3d. per 1000 gallons . . .	5,475	0	0
	£45,475	0	0

EXPENDITURE.

Annual expenses, taxes, &c. &c.	£15,725	0	0
Say, capital expended (including £10,000 for Act of Parliament) £350,000, at 8½ per cent. .	29,750	0	0
	£45,475	0	0

The above estimate for constructing the works supposes that the whole of the eight millions of gallons per day be distributed to tenants below the principal reservoirs at Stanmore. The working

expenses, however, include raising half a million of gallons per day to the high-service reservoir, as probably in a few years, this quantity will be taken therefrom to supply the inhabitants of Hampstead and other elevated districts. In such places, it may be necessary to make a slightly increased charge to compensate for the extra height to which the water must be lifted, and the more dispersed situations of the houses. In thinly peopled districts the charge must also be regulated by the number of houses to be supplied from a given length of pipe, and become the subject of special agreement. However, the demand for water is so great within the districts through which the main pipes are proposed to be laid, and especially in the elevated parts, that there can be little doubt remunerating customers in such parts will soon be found.

The raising water by steam power forms but an small portion of the expense of distribution, even when lifted to a considerable height.

This will be understood, from stating, that the cost of raising daily, seven and a half millions of gallons from Bushey Meadows to the principal reservoirs at Stanmore, and half a million of gallons, daily, to the high service reservoir, including ten per cent. on the cost of the engine, engine-house, boilers, and pumps, with the annual cost of coals, wages, etc. etc. only amounts to £9900 per annum, being at the rate of two shillings and sixpence per annum for every house supplied with a hundred gallons per day. The interest on capital invested in

pipes and reservoirs, with the annual cost of taxes, collection of rates, management, etc. etc., form by far the largest items of expenditure.

Indeed, it frequently happens, that lifting water to a considerable height, for the purpose of distribution, saves expense (as in the present case), by permitting smaller mains and distributing pipes to be made use of than would otherwise be efficient, and thus economising the first outlay.

To recapitulate,

It may be observed,

First.—That there exist at Bushey Meadows, near Watford, deep springs, rising to an elevation of 160 feet above London (fed from the rain falling upon a large area of absorbent upland), capable of yielding an enormous amount of water, which at present runs to the sea through underground fissures, and is unappropriated.

Secondly.—That this water is remarkably free from organic matter, at all times perfectly pellucid, and when collected and allowed to remain for a short time in reservoirs suitable for distribution, is as soft, or softer, than the Thames water.

Thirdly.—That the source from which this water is obtained cannot diminish in yield, nor become polluted from the increase of population, or from any other cause.

FOURTHLY.—That the procuring and distributing for domestic consumption in London and Westminster, upon the approved principle of high pressure and continuous supply, eight millions of gallons of this water daily, may be effected at a cost of £350,000; upon which sum, at the average annual rental of twenty shillings for every house supplied with 170 gallons daily, a return of eight and a half per cent. per annum will be obtained.

IN CONCLUSION, I would add, that I sincerely hope the principle heretofore acted upon, of leaving to capital and public enterprise the supply of water to the metropolis, will never, under any pretext, be infringed. I would remind those who are advocates for government interference, and for the "absorption "of all interests and works for the supply of water "into one great scheme and management of a very "public character," * that government superintendence in matters of detail, is more likely—as experience proves—to be injurious than beneficial to the general weal, and that under such management, all errors of omission and commission are at once, and *for ever*, saddled upon the public, and the progress ensured by competition is immediately annihilated.

The evil result of entrusting to irresponsible local governments the supply of this necessary article is practically exemplified in several of our large towns, and I trust, will serve as a warning to the metropolis.

* Paper "On an Extended and Improved Supply of Water to the Metropolis," by CAPT. JAMES VETCH, R.E.

I have herein avoided remarking upon other projects, having a similar object to yours—the nature of these will be best explained by their respective authors. I feel assured, upon comparison, that the SOURCE, QUALITY, DISTRIBUTION, and COST of the water you propose to collect will meet with general approbation; and that, to quote the words of Mr. R. STEPHENSON, "it is scarcely possible to believe "that any who are interested in the supply of the "metropolis with pure water will hesitate to assist "you in carrying out your project."*

I have the honour to be,

GENTLEMEN,

Your obedient servant,

S. C. HOMERSHAM, C.E.

19, Buckingham Street, Adelphi.
January 8th, 1850.

* Second Report, dated 1841, to the London and Westminster Water Company.

APPENDIX.

APPENDIX A.

ON THE QUALITY OF WATER.

The impurities found in waters may be divided into three classes. 1st—Impurities resulting from the amount and character of the saline matter in solution. 2nd—The impurities resulting from the mixture of extraneous matter held in suspension. 3rd—The impurities resulting from the amount of organic matter, held both in solution and suspension.

First; the Watford spring-water and the water at present supplied to London by the several Companies, are very similar, both in the character and the amount of their saline constituents, which consist principally of salts of lime.

Second; on comparing the Watford spring-water, either with the Thames, the Lea, or the New River, it is found to be superior in every respect, even to the best filtered water supplied by any of the London Companies, being brighter, clearer, and at all times free from any matter held in suspension.

Third; it is, however, in this, the *most important respect*, that the Watford, and indeed all other spring-water, is superior to river-water, and especially to that of the Thames and Lea. It is *organic* matter in water that renders it unwholesome, unfits it for drinking and culinary uses, makes it offensive to the smell in warm weather, causes diarrhœa, and nourishes innumerable insects. The amount of organic matter absorbed or dissolved by river-water, and especially the Thames, and rivers receiving the ejecta of a numerous population, is very much greater in summer and autumn weather, than at any other season. It would be as idle to seek for any large amount of organic matter in river-water, in cold frosty weather, as to expect a river fed by the drainage of cultivated lands, and receiving the refuse of numerous towns, to be free from it in warm weather. *Warmth* is necessary to enable water to take up organic matter in solution, and the heat acquired by rivers in summer favours its putrefaction.

River-water varies considerably in temperature at different seasons of the year. James Glaisher, Esq. of the Royal Observatory, Greenwich, in his invaluable quarterly remarks on the weather, states, that in 1848 the mean temperature of the Thames water during the quarter ending March 31st, was 39·3 degrees by day, and 37·0 by night, being 2·4 warmer than the air. In the quarter ending June 30th, it was 60·7 by day, and 59·6 by night, being on an average 3·6 warmer than the air. In the quarter ending September 30th, it was 63 degrees by day, 62 by night, being on an average 3·9 warmer than the air. In the quarter ending December 31st, it was 47·5 by day, and 45·7 by night, being on an average of the same temperature as that of the air.*

It is in summer, *when rivers are warm and the smallest in volume*, and water is most used for all domestic

* See Appendix B, page 29.

purposes, especially for drinking, that excremental or decomposing vegetable matter becomes *freely* soluble. At the last meeting of the British Association at Birmingham, it is reported, that "Professor FORCHHAMMER, continuing "for a whole year every week his analysis of the water "which is used for supplying Copenhagen, observed the "following facts: 1st—The quantity of organic matter is "greatest in summer. 2nd—It disappears for the most "part as soon as the water freezes. 3rd—Its quantity is "diminished by rain. 4th—Its quantity is diminished if "the water has to run a long way in open channels."* This is in accordance with every day's experience, and corroborates the deductions from some extensive experiments I had occasion to institute in 1847, which proved that organic matter introduced into water was dissolved, to a greater or less extent, according to the *warmth* of the water and the *duration* of its immersion. It must, however, be remembered in reference to the fourth observation, that although organic matter be diminished in water running a long way in open channels, to attain this object such channels must be clean, and not have poured into them faded blossoms and fallen leaves, or the grosser impurities which are cast away from numerous and populous towns and villages; otherwise, the impurity instead of diminishing increases at every step, as is shewn to be the case with the Thames, in a valuable paper† read by Dr. R. ANGUS SMITH, of Manchester, at the meeting of the British Association in 1848, and published in its report, page 26. He states, "The Thames water is at "first pure, as far as freedom from organic matter occurs, "and takes its course through a rather level country. "The stream is soon filled with plants; and at Kemble

* On a New Method of Determining the Organic Matter in Water, by Professor FORCHHAMMER, *Athenæum*, Sept. 22nd, 1849, page 964.

† On the Air and Water of Towns.

"the water has already taken up some organic matter, "enough to form a slight green deposit on standing. The "water here is still beautifully clear, and is good water; it "is 15·5 degrees of hardness.

"When we come down toPangbourne, the water cannot "be said to have become much worse; it is still so pure "as to require a considerable time to form a deposit, and "that only small, containing a few plants and some small "animalcules from 1-2000th to 1-3000th of an inch. "Here there is a slight but still decided trace of organic "matter from animals. There has been an increase in "hardness also:—

			Grains of Soap.
"Seven Springs . .	12·75	of hardness	262
"Andover Ford . .	13·88	„	283
"Thames Head at Kemble	15·5	„	312
"Church at Cirencester	15·7	„	315
"Reading . .	16·5	„	340

"Pangbourne was only 15·4 in November, 1847; the "*others are of February*,* 1848, when the water was harder "down to London. There is seen here an increase in "hardness, and there is also an increase in soluble salts not "contributing to the hardness. At Seven Springs the "hardness is equal to the whole amount of insoluble salts "and a fraction more, which may arise from an excess of "carbonic acid.

			Grains.
"At Seven Springs inorganic matter in a gallon			12·25
"At Pangbourne	„	„	22·33
"At Reading	„	„	23·114

"At Windsor animalcules begin to shew themselves "more prominently in the water, and these rather large "Hydatina. There are also at Reading and Oxford "some of the smaller green Naviculæ, and several other

* Average temperature of river Thames in February, 1848, according to Glaisher, 41·1 Fahrenheit.

" smaller green Bacillaria. Oxford water had more of " these than Reading, and also a large amount of matter " in solution; it is probable that the soil through which " the Isis flows, is rather different from the other part of " the Thames. The river was rather high at the time.

" From Richmond downwards, the case is much al- " tered, and the water, although clear, gives after a time " a brown flocculent deposit entirely distinct from the mud " deposit which had been carefully removed beforehand. " This flocculent deposit contains many animals, large and " gelatinous-looking; also below Chelsea, and chiefly below " Hungerford Market, little eels, '*vibrio fluviatilis,*' about " 1-30th of an inch long." He adds, " There is then a great " deal of matter in a state capable of being converted into " living forms; this matter is not *in suspension merely,* but " *in solution* also. A large quantity of organic matter is " precipitated in contact with clay and mud in the Thames, " *but a great deal is also in clear solution.*"

It is this matter, which in warm weather (even after filtration), being held in invisible solution, *and becoming putrid by warmth,* renders the Thames water unwholesome. In the Appendix to the Illustrations of the Croton Aqueduct,* written by Charles A. Lee, M.D., it is stated, p. 136—" River-water always contains a greater " or less quantity of organic matter in suspension or " solution. As a general rule, the quantity is too small to " produce any decidedly injurious effect; but physicians " and medical writers agree in the opinion that water im- " pregnated with it to any great extent must be dele- " terious. Where the decomposing matter is too small " to produce any immediately obvious effects, it is difficult " to procure any decisive evidence of its influence on the " system. When the amount is considerable, it causes *dy- " sentery* and *fevers,* often of a highly fatal character."

Any one requiring to prove the presence of organic

* Wiley and Putnam, New York, 1843.

matter in Thames water, need only fill a glass bottle with it in the month of July or August, and keep it closely corked three or four weeks, exposed to the ordinary temperature of the atmosphere. On drawing the cork, a disgusting odour is emitted, arising from the putrefaction of organic matter. Two bottles filled at Richmond in February, 1849, one from a pipe of the Water Company deriving their supply from the Thames, and the other with the same water passed twice through an ordinary house filter, were opened in the presence of myself and others in the month of September last: the contents of both emitted the most offensive stench, and a large quantity of gas. This simple experiment is a convincing proof of the organic matter contained in Thames water; if any other proof be required than the presence of insects abounding in it in warm weather.

A bottle of the Watford spring-water, corked and kept in the same manner, emits no smell whatever, owing to its freedom from organic matter. Spring-water at all seasons, whether in the depth of winter or in the middle of summer, is free from organic impurity, and it is probably on this account, that it is always instinctively sought after as a beverage.* The spring-water, as proposed to be supplied from Watford to London and its suburbs, is subject to no possibility of contamination during its transit. It is intended to be lifted from the springs through cast-iron pipes over cascades into two large reservoirs entirely lined with hard-burnt bricks set in cement, it will then flow from these reservoirs through a line of pipes over another cascade into a distributing reservoir (of a similar construction to the last) situated at Child's Hill, from whence it will be conveyed by cast-iron pipes to the consumers; so that, unlike any other water supplied to London it will be distributed as free from organic pollution as when it first flowed from the spring.

* See Appendix P, page 53.

APPENDIX B.

I have been favoured by James Glaisher, Esq., of the Royal Observatory, Greenwich, with the following Table, compiled from observations taken daily by Lieut. Sanders, R.N., superintendent at the Dreadnought Hospital Ship lying at Greenwich.

The thermometers used are self-registering, and suspended from the side of the ship, to the depth of about 2 feet below the surface of the water in a perforated tank.

It is much to be regretted, that the examination of the specimens of the Thames water undertaken by Dr. Angus Smith, of Manchester,* was made upon water collected in the month of February, 1848, instead of August or September, in which last named months organic matter abounds in the water of the Thames.

Temperature *of the* Thames Water *in every month, from January*, 1846, *to December*, 1849.

MONTH.	1846.			1847.			1848.			1849.		
	Mean of all readings.			Mean of all readings.			Mean of all readings.			Mean of all readings.		
	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.	Max.	Min.	Mean.
	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.	Fahrt.
January	44°3	42°0	43°2	37°1	35°5	36°3	35°7	35°1	35°4	41°6	39°6	40°4
February	45 3	42 5	43 9	38 9	37 2	38 1	41 8	40 3	41 1	44 2	42 6	43 4
March	48 2	46 3	47 3	42 1	41 4	41 8				45 7	44 1	44 9
April	51 5	49 4	50 5	46 9	46 4	46 7	51 1	50 2	50 6	47 9	44 8	46 3
May	59 9	57 2	58 6	58 6	57 0	57 8	62 5	61 0	61 8	58 9	55 7	57 3
June	73 0	70 8	71 9	65 5	61 9	63 7	63 6	62 6	63 1	65 2	63 3	64 3
July	67 4	66 1	66 7	70 6	66 5	68 6	66 0	65 0	65 5	67 8	66 1	67 0
August	68 3	66 7	67 5	66 1	64 4	65 3	63 0	62 0	62 5	64 9	62 7	63 8
September	64 7	63 5	64 1	57 0	56 5	56 8		58 8	59 5	61 4	58 7	60 0
October	54 2	52 8	53 5	53 3	53 0	53 2	53 7	50 8	52 2	52 8	49 5	51 2
November	47 6	46 0	46 8	47 9	47 3	47 6				47 1	44 1	45 6
December	37 6	34 9	36 3	42 5	41 5	42 0	43 9	40 5	42 2	40 3	36 8	38 6

* Report of the British Association in 1848—Paper "On the Air and Water of Towns," by Dr. R. A. Smith of Manchester.

APPENDIX C.

ON THE SOFTENING OF SPRING-WATER IN RESERVOIRS.

In a valuable paper by the late Dr. Dalton, published in the third volume, second series, of the Memoirs of the Literary and Philosophical Society of Manchester, and read April 1st, 1814, it is stated, page 61—"When spring-" water is used by manufacturers for washing, etc. it is " advantageous to have it some time exposed to the at-" mosphere, in a reservoir with a large surface. This " exposition suffers the carbonic acid in part to escape, " and the carbonate of lime to precipitate; and in some " degree supersedes the necessity of boiling the water. " The more any spring is drawn from, the softer the " water becomes, it should seem. I have this morning " examined a spring which yields many thousand gallons " every day. The water is comparatively soft; it does " not curdle scarcely at all with soap; it is very nearly as " soft as the before-mentioned pump-water boiled. The " hardness in it arises from a little sulphate of lime, and " a little carbonate."

APPENDIX D.

The following is an extract from a valuable report lately printed and distributed in Hull, entitled

"REPORT ON THE HULL WATER,"*

BY

ARTHUR AIKIN, F.G.S., &c.,

AND

ALFRED SWAINE TAYLOR, M.D., F.R.S.,

Professors of Chemistry in Guy's Hospital.

"Two specimens of this water were submitted to chemical analysis,—the one UNFILTERED, marked No. 1, and the other FILTERED, marked No. 2.

"Analysis of UNFILTERED Water, No. 1.

Contents of No. 1.—Imperial gallon.	grains,
Carbonate of lime, with traces of carbonate of magnesia	6·2
Sulphate of lime, oxide of iron, and silica . .	2·4
Chloride of sodium (common salt) . . .	4·0
Chlorides of calcium and magnesium . . .	2·2
Organic matter (animal and vegetable, containing sulphur)	3·2
Total solid contents in imperial gallon .	18·0

"N.B. The saline residue was expressly examined for phosphates, soluble and insoluble, but no trace thereof could be found to exist in sixteen ounces of the water.

"It may be observed of this water, that the proportion of saline and organic matter contained in it does not differ materially from that found in the water of the Thames at Teddington *(above the influence of the tide)*;

* November 8th, 1849.

and in the water of the New River, by which a large part of this metropolis is supplied, namely, in the imperial gallon :—

Hull, unfiltered water, No. 1 . .	18 grains.
Thames water (Teddington) . .	17·4 „
New River water . . .	17 to 19·2 „

"The fractional proportion of saline matter (including organic) contained in this water (No. 1) amounts to 1-3888th part by weight, while in the Thames at Teddington it amounts to 1-4020th part by weight.

"Analysis of FILTERED Water, No. 2.

Contents of No. 2.—Imperial gallon.	GRAINS.
Carbonate of lime, with traces of carbonate of magnesia	7·2
Sulphate of lime with traces of oxide of iron and silica	0·8
Chloride of sodium (common salt) . . .	2·5
Chlorides of calcium and magnesium . . .	2·5
Organic matter	3·0
	16·0

"The saline residue was examined for soluble and insoluble phosphates, but none were found in sixteen ounces.

"These specimens of water were collected for analysis, March 31st, 1849."

APPENDIX E.

INTERMITTENT AND CONSTANT SUPPLY.

In London, and some other towns, water is only delivered by the Companies to their tenants during one or two hours per day, for two or three days in the week; or, as lately practised by some Companies in London, for a short time every day.

It thus becomes necessary for every house to have one or more tanks, cisterns, or butts, to receive the water when supplied, and store it for use. This system was first introduced, owing to the great leakage and loss which took place when the distributing pipes were made of wood, which rendered it desirable to have such pipes charged with water as short a time as possible, and to shut it off as soon as the cisterns or butts, before alluded to, were filled. At one time the New River Company alone had different trains of wooden pipes about 400 miles in extent; but since the year 1811, cast iron-pipes have gradually superseded them, and are now universally adopted: from the accurate manner in which the joints of cast-iron pipes can be made, little or no leakage results; and in many towns—for instance, Edinburgh, Bury, Ashton-under Lyne, Dukinfield, Preston, and other places—these pipes are kept constantly charged with water, and the tenant draws his supply through a small communicating pipe, as with gas.

This system, which was introduced in Edinburgh as early as the year 1819, has many advantages, especially with small houses, as, both the room occupied and the cost of the tank is saved, besides the water being insured against the contamination which frequently takes place in butts or cisterns.

Knowing that a water company formed at Wolverhampton in 1846, commenced distributing upon the old system, but has lately discontinued it, and has adopted the more modern one of continuous supply, I wrote to Mr. H. Marten, the resident engineer, to give me the result of his experience of the two systems, and received the following answer :—

"Engineers' Department,
"Wolverhampton Water Works,
"*December* 17*th*, 1849.

"Sir,

"In reply to yours of the 7th instant, I have great pleasure in submitting to your notice the following results of the experience of these works in regard to the practical working of the intermittent and constant systems of supply.

"It will be necessary to state that these works were designed to give a supply on the intermittent plan, and were constructed in all their details with a view to carry out to their fullest extent the principles of that system.

"The works were opened early in 1847, but notwithstanding the advantages of construction, and a diligent canvass of the new and wide field of operation open to us, consisting of nearly 7000 houses, the impression made was exceedingly feeble.

"The inhabitants constantly met us with objections as to the expense and inconvenience of erecting tanks, and as to the mode of supply; and these were so great a bar to our progress, that at the end of nearly two years the company found themselves supplying only about 600 tenants, being at the rate of 26 per month.

"Having thus gained a dearly bought experience of the practical difficulties and daily inconvenience connected with the working of the intermittent system, it was determined to try the continuous supply, but partially only at first.

"The marked success which attended even our first steps in this measure was at once so apparent, that it soon induced the full introduction of the whole system, and although it has not been in operation more than about 10 months, the houses in supply have during that period increased from 600 to more than 1400, or at the average rate of about 80 per month, being a ratio of increase more than 200 per cent. greater than under the old system.

"The rapid increase of tenantry is however one only of the many advantages we have derived from giving the constant supply.

"We find that the consumption of water under this is less than under the intermittent system by more than 20 gallons per house per diem.

"This remarkable result, which at a first glance would appear contrary to what might be expected, is caused thus:—when the water is always on, the tenants draw only so much as they absolutely require; but when it is intermittent, they almost invariably draw more than they actually want, to guard against any contingencies which may happen before the next supply comes on, when a large remnant from the previous collection is thrown away.

"We find also a very considerable economy in the cost of distributing the water, as under our present system no service of turncocks is necessary, and the wear and tear of the cocks and pipes is much reduced.

"In conclusion, therefore, although the experience of the constant supply system at these works is of short

duration, it is fortunately of so distinct and definite a character that its results are easily summed up.

"To the company, independently of the increase of custom it induces, I find it decidedly the more economical, inasmuch as it requires a smaller expenditure of capital, and lessens the working expenses.

"With the consumer also it is decidedly and deservedly the more popular, because it does away with the necessity for the erection of an expensive and inconvenient apparatus, reduces to a minimum the first cost of obtaining a supply, and because, when supplied, it is in every way more suited to his domestic convenience.

"I have the honour to be, Sir,

"Your obedient servant,

(Signed) "HENRY MARTEN.

"S. C. Homersham, Esq.,
"19, *Buckingham-street, Adelphi.*"

APPENDIX F.

Public attention having been lately called to the circumstance, that the level of the water, in many deep wells under London, sunk through the blue clay to the plastic clay, or chalk, has been lowering for several years past, and that at present the level of such wells is 60 feet below Trinity high-water mark, or 47½ feet below the mean level of the sea, it may be as well to explain the reason of this fact.

The chalk under the London clay communicates with hills of the same formation in Hertfordshire, Berkshire, Buckinghamshire, and Hampshire, varying from 400 to 1000 feet in height, and also under Essex with the sea. Beneath this chalk is found a stratum of clay, retaining that portion of the rain which, absorbed by the almost bare chalk hills, percolates downward through their fissures, and accumulates until it finds a vent at the coast. Thus, before wells were sunk through the London clay, a constant supply of fresh water was maintained under it by the rain that fell on the chalk hills and the outcrop of the plastic clay (lying between the London clay and the chalk); but when many wells were sunk, and powerful steam engines were erected to raise this water, *as soon as more was lifted than could be supplied through the small pores of the chalk underlying the London clay*, the level of the water was gradually reduced to its present depth of 47 feet below the sea, and the same fissures which formerly served as a partial outlet for the upland water, became the means of admitting sea-water, to replace that thus abstracted.*

An analysis by Professor Brande, given in a lecture at the Royal Institution in 1846, gives 66 grains as the

* See section on Geological Map, at end of book.

saline contents of a gallon of the deep-well water at Charing Cross, 59·9 *grains of which were stated as common salt and soda.*

The total saline constituent of water when first procured from the deep springs at Watford, *which are above the level of the sea*, does not exceed 21·2 grains per gallon; 17·4 of which are salts of lime, and 9-10ths of a grain magnesian salts, leaving but 2·9 grains of any other salts: this is conclusive evidence of the difference of the water procured from the chalk under the London clay, *below* the level of the sea, and that procured from the fissures in the chalk formation *above* the same level.

When the immense weight and thickness of the blue clay, superimposed upon the chalk under London, is remembered, the compactness and impervious character of this chalk is easily accounted for, and will explain why only a limited quantity of water can find a passage through from the uplands.

APPENDIX G.

The following is extracted from *Rees's Cyclopædia*, article "Spring," edition 1819.

"The porous rocky chalks are excellent conductors of "water, where they have only a thin covering of an ab-"sorbent loamy material, as they imbibe, after the surface "soil has been saturated, every particle of water that "may come upon them, in the form of rain or otherwise. "This is seen to be the case in many hilly situations "formed chiefly of such matters, in the south-west parts "of the kingdom, as in the counties of Wilts and Dorset. "The water which is absorbed and taken up by so porous "a substance as chalk, soon escapes the power of evapo-

"ration, and continues to descend, in the manner of that "which passes through a filtering stone, until it meet "with an impervious or non-conducting stratum or layer, "upon which it collects; and if this surface, on which it "is collected, should lie above the level of the sea, or "other collection of water, it forces its way out in the "manner of a spring or more copious fountain; not always "in one constant stream, but often periodically: the "springs of chalk hills differing in this respect, from those "of the more open conducting kinds; which is a fact that "is entitled to be more fully and philosophically inves-"tigated. The action or operation of the waters of chalk "hills, is most clearly seen on the sea coasts, where the "bases of the chalk cliffs rest upon an impervious or non-"conducting stratum or bed, which being softened and "worn away by the impression of the waters collected "upon it, the cliffs are undermined, and the faces of them "thrown down.

"Where the base of the chalk dips beneath the surface "of the sea in low tides, the whole collection of water "regains its 'native home' unseen. And it is not "doubted but that much rain-water, passing through "other strata, finds its way to the sea in a somewhat "similar manner."

APPENDIX H.

In March, 1840, Mr. R. Paten gave evidence before a select committee of the House of Lords (appointed at that time to consider the question of water-supply to the metropolis), upon the desirability of procuring pure water for London from the deep springs abounding in the chalk formation near Watford.

In consequence of his evidence, Mr. Paten, on March 13th, 1840, received from the late most noble the Marquis of Westminster (chairman of the committee) the following order:—

(COPY.)

"Mr. Paten,

"You are ordered by the Committee of the House of Lords "to make an experiment, and prove to their Lordships that "an abundant supply of water from Bushey Hall Mea-"dows can be obtained for London.

(Signed) "WESTMINSTER."

Extensive experiments were immediately commenced, and carried on until the 24th October, 1840, and are described in the following letter:—

"Watford, Herts,
"*December* 3, 1849.

"Dear Sir
"To comply with your request, I send you some practical facts connected with the chalk formation from which I have procured large quantities of water.

"I shall commence by describing some experiments ordered in March, 1840, by a committee of the House of Lords, to be carried out in the valley of the Colne, near Watford. Twenty small borings made at different portions of this valley (about 2 miles in length by three-quarters of a mile in breadth), proved that almost any quantity of water was here obtainable: one of these borings in the upper part of the valley, only $5\frac{1}{2}$ inches in diameter and 130 feet deep, was found to yield 200,000 gallons per day of 24 hours, and one of 12 inches diameter 134 feet deep, in the lower part, yielded upwards of 600,000 gallons in the same time, shewing that the quantity obtainable was regulated by the size of the boring.

"A shaft 12 feet 6 inches diameter and 34 feet deep, penetrating only 8 feet in the chalk springs, with 4 small borings in the bottom of 5 inches diameter and 130 feet deep had raised from it 1,800,000 gallons per day without exhausting the water, and, I am sure, if the engines had been sufficiently powerful, this well would have produced double that quantity.*

"In boring through the chalk in the valley of the Colne various beds of hard chalk-like rock are encountered; these vary in thickness from 12 inches to 8 feet, and below them are found large fissures or cavities from 12 inches to 12 feet in depth, strongly charged with water.

"As a precaution to prevent the tool, with the immense weight of rods, falling to the bottom of these fissures when breaking through the rock, the men have a check rope regulating the fall to about six inches. To ascertain the depth of water below these rocks (or, as the well borers call them, pans), I have had the rods lowered, and found the water to vary, as above stated, from 12 inches to 12 feet: the pressure of the water when many of the rocks are perforated is so great that the chisel and rods can be turned round by the most trifling power although it previously required great leverage to move them. I have made borings higher up in the chalk ridge, and have not found these rocks; but even there a large quantity of water has been obtainable from fissures in the chalk, although by far the greatest quantity is procured in the valley below these rocks. This, however, is nothing new, all practical men are acquainted with it. I know a person who bored in the salt marshes at Woodbridge, in Suffolk, to a depth of 200 feet when the rods came into a bed of water 18 feet deep. The same person made a boring for the parish authorities of Wickstead, in the same county, 380 feet deep, and met with a bed of water

* See Plate, page 42.

20 feet in depth ; these fissures have also been found by M. Arago, at St. Omers, in France, where he states, 'five 'distinct sheets of water were intersected in one boring, 'and from each a supply obtained; in the third water-'bearing stratum at the depth of 150 feet, the auger drop-'ped a considerable depth, when the water ascended in a 'great volume.' M. Arago also mentions an Artesian well at Fontainebleau, 'where the boring rods all at 'once' (as in Suffolk) 'descended nearly 28 feet, and when 'it was attempted to withdraw them, it was evident they 'were suspended in a body of water, the current of which 'was so strong as to occasion the instrument to diverge 'in a particular direction.'

"M. Arago intercepted five distinct sheets of water in one well, and I have also found several of these streams in many borings made by me.

"Dr. Ure, in the article 'Artesian Well,' inserted in the Supplement (edition, 1846) of his valuable *Dictionary of Arts, Manufactures, and Mines*, states, that in sinking the celebrated well at Grenelle, 'after eight years' labour, the 'rods *suddenly descended several yards*, having pierced 'into the vault of the subterranean waters so long sought 'after by the indefatigable engineer. A few hours after-'wards he was rewarded for all his anxious toils ; for lo! 'the water rose to the surface and discharged itself at the 'rate of 600,000 gallons per hour.'

"It appears, therefore, that the fissures I have described as existing in the valley of the Colne have also been found in many other places.

"I am, dear Sir,

Yours very faithfully,

(Signed) "ROBERT PATEN.

"To S. C. Homersham, Esq., C.E."

Section of Experimental Well,

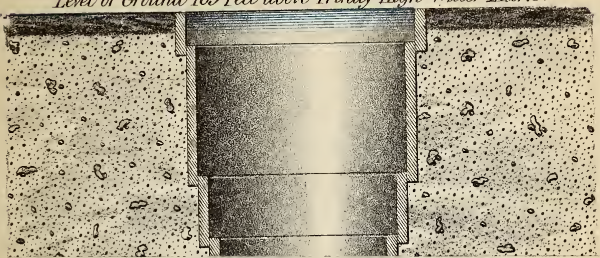
AT

BUSHEY MEADOWS, HERTS.

Sunk by order of

SELECT COMMITTEE OF HOUSE OF LORDS.

1840.



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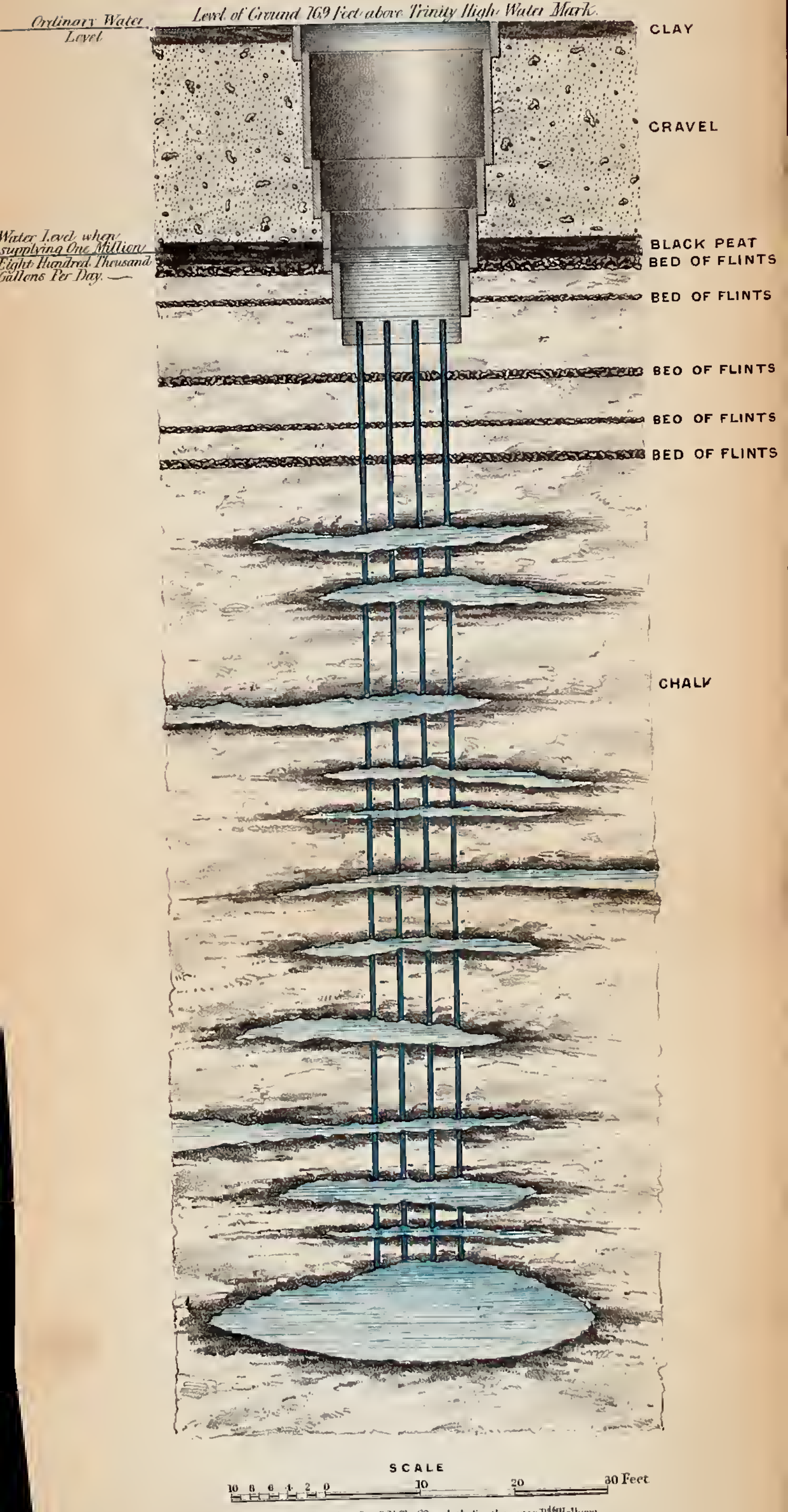

Printed in Colors by C. F. Cheffins, Lith. Southampton Bdgs Holborn

APPENDIX I.

"MariscHAL College,
"*December* 26*th*, 1849.

"My Dear Sir,

"I have made a careful preliminary examination of the Watford spring-water. I wish still to examine the water in some additional particulars, as well as to verify some of the results that I have already obtained; and I hope at a further period to send you a more ample and formal report; but, in the mean time, it may be satisfactory to you to be aware of the principal conclusions I have arrived at.

"The water appeared to me to be of an excellent quality of spring-water. Under examination it manifested the character of a water singularly free from organic matter. The water is 17½ degrees of hardness. Each degree of hardness stands for as much hardness as would be produced by dissolving one grain of chalk in a gallon of distilled water, by means of carbonic acid, sulphuric, or any other acid.

"Minute numerical results I will give afterwards; meanwhile I may mention, that all the above 17½ degrees of hardness are due to salts of lime; of which almost the whole consists of chalk (i.e. carbonate of lime, an alkaline salt) held in solution in the form of bicarbonate of lime.

"In addition to these salts of lime, amounting to 17½ degrees of hardness, the water contains a small quantity

of magnesian salts; but these in the presence of so much lime, do not destroy soap, although they make the soap that the lime destroys a little curdy; but any change that would bring the lime down below 10 or 12 degrees of hardness, would bring this magnesian portion of the salts into action upon soap.

" None of the other salts present in the water affect its hardness.

"A hundred gallons of the water as it comes from the spring, require 36 oz. of curd soap in order to form a lather.

" The water seems to contain very little uncombined carbonic acid, or of any other gas. Exposure to the air has the effect of softening it. In order to ascertain at what rate, I put about 3 inches depth of it into a circular green glass vessel (made for dairy use) which widened towards the top. The average diameter was about $12\frac{1}{2}$ inches. At least a half of the water was used up in making successive trials upon it, during a period of three weeks. Thus exposed, I found the water to soften at the rate of about a quarter of a degree per day, and also to require, for producing a lather with 100 gallons of it, about 3oz. less of curd soap at the end of each week.

" Filtration applied to this water would be a superfluous process.

" I tried upon it the effect of the lime-softening process. For this purpose part of the water was converted into lime-water, by the addition of slacked lime; two measures of this lime-water were mixed with nineteen measures of the water itself. The two clear waters became perfectly white, from deposited chalk, like a weak white-wash; but within six hours the mixture seemed to clear very well. Tried at the end of 24 hours, the hardness was only $3\frac{1}{4}^{\circ}$ instead of $17\frac{1}{2}^{\circ}$. At the end of other five days, the hardness was only 3 degrees. In

100 gallons of the softened water a lather could be formed with 7oz.

"I have not met with any water that answers the lime process of softening better than the Watford spring-water.

"All the rivers within reach of London, so far as they have been examined by other chemists, or by myself, appear to be naturally of one quality; they are all chalk waters, differing by about 4 or 5 grains per gallon in the saline matter that they contain; but all with nearly the same kind of saline matter.

"This Watford spring-water is of the same kind, only it has the advantage of being a spring-water instead of a river; just as if, instead of deriving your supply from the Thames, you took it from one of the uncontaminated springs that feed the Thames. I say that the saline matter in the Watford spring-water is of the same kind as the river-water contains; meaning that it is of a very different kind from what is found in the deep spring-waters below the London clay, commonly (however erroneously) called Artesian well waters; respecting which, as the only considerable source of supply of another quality of water within reach of London, I will take a brief notice.

"In the deep spring-waters alluded to, there is a large quantity of bicarbonate of soda; 28⅓ grains per gallon, according to the recent analysis in the Royal College of Chemistry, upon the water at Trafalgar Square. There are also *other* 51·3 grains of saline matter present; say 79½ grains per gallon in all. When boiled, this bicarbonate of soda is reduced to carbonate of soda, and its alkaline taste may then be easily recognized in the water. A solution of carbonate or bicarbonate of soda, of this strength, will act medicinally on the kidneys. By calculation from the analysis alluded to, the hardness of the 'Artesian' water is 5°9, which nearly agrees with my own experiments in

this and other deep waters in London; 100 gallons of it would form a lather with 13oz. of curd soap.

"I remain, my dear Sir,

"Yours respectfully,

(Signed) "THOS. CLARK,

"*Professor of Chemistry in the University of Aberdeen.*

"S. C. HOMERSHAM, ESQ., C.E."

APPENDIX K.

IN the south of England the area of the chalk formation, almost bare, or only slightly covered with porous layers, consists of 4117 square miles, as measured upon Knipe's Geological Map. The average annual depth of rain falling upon this area of chalk country will be certainly under than over-rated at 20 inches; and allowing that as much as one-half of this quantity either finds its way to rivers, or is consumed in supporting vegetation and evaporation, still 10 inches in depth remains to percolate down through the fissures of chalk, till, arrested by the impervious clay which lies beneath, it accumulates in fissures, or faults, to such a height as to occasion sufficient hydrostatic pressure to cause its exit by subterraneous drainage to the ocean.

The depth of 10 inches of rain per annum percolating through an area of 4117 square miles, is equal to a supply of 1595 (one thousand five hundred and ninety-five) *millions of gallons of water for every day in the year*; and this quantity is the least which *must* find an outlet at the sea-coast.

APPENDIX L.

The following parishes included in the parliamentary powers of the London (Watford) Spring-Water Company are at present unsupplied by any works:—

NAME.	Population in 1841.	Increase to 1850, calculated at 1 per cent. per annum.	Population in 1850.
Willesden	2,930	264	3,194
Hampstead........	10,093	908	11,001
Hendon	3,327	300	3,627
Kingsbury	536	48	584
Edgware	659	59	718
Little Stanmore	830	75	905
Great Stanmore	1,777	160	1,937
Bushey	2,675	241	2,916
Watford	5,989	539	6,528
Elstree	360	32	392
Harrow-on-the-hill..	4,627	416	5,043
Pinner	1,331	120	1,451
Totteridge	469	42	511
Finchley	3,664	330	3,994
	39,267	3,534	42,801

APPENDIX M.

The following analysis of seventeen samples of water, made by the eminent chemist, William Thomas Brande, Esq., F.R.S., V.P.C.S., &c., early in March, 1849, is extracted from a pamphlet containing some valuable information, entitled "*Remarks on the Water Supply of London*," by Sir William Clay, Bart., M.P., &c. &c.*

Analysis of Samples of Water.

NAME.	Clark's Test.	Solid contents in one gallon.
	Degrees.	Grains.
New River	15½	20
New River	16	21
New River	16 1/10	21
Southwark and Vauxhall....	16	21·5
Southwark and Vauxhall....	15½	20·1
Thames, Medmenham or Henley	17	22·5
Chelsea	16½	22
Chelsea	16	21·2
Chelsea	15¼	23
Chelsea	15¾	21
Chelsea	15¾	21·1
East London	17	22·3
East London	17¼	23
Grand Junction	15¼	20·5
Grand Junction	15¼	20·1
Grand Junction	15¼	21
West Middlesex	14 1/10	19·5

* Published by Ridgway, 1849.

APPENDIX N.

In a valuable report made to the directors of the London and Westminster Water Company, by Mr. R. Stephenson, and published in 1840, the following observations occur :—

"It is almost needless that I should inform you, that "of the water which descends as dew or rain upon the "surface of the London clay, little, if any, can be con- "sidered as absorbed into the earth; and that whilst a "part either again re-ascends into the atmosphere as "vapour, or enters into the composition of animal and "vegetable bodies, by far the greater portion flows off "into the main drain of the district, the river Thames.

"In this respect there is a most material difference "from that portion of the surface where the chalk comes "to light, divested of any covering which could intercept "the passage of the moisture; being not only extremely "porous, but also full of fissures in every direction, a "very rapid absorption takes place, and we accordingly "find that there are but few streams carrying off the "surplus surface water, and that these are insignificant, "and, indeed, many of them dry during the greater part "of the year. The rapidity with which the water finds "its way into the bowels of the earth, also, in a great "measure prevents evaporation; and we are therefore "justified in assuming, that the quantity which descends "upon the surface of the chalk finds its way, with very "slight diminution, into the fissures below. The lower "beds of the cretaceous group, and the gault which im- "mediately succeeds it, again present an impermeable "stratum of clay, causing the water to accumulate "through the lower regions of the more porous chalk.

"An enormous natural reservoir has thus been formed, "and the level up to which it may be considered as quite "full of water is the lowest point where it can find a "vent and overflow; therefore, as the chalk communi- "cates under the coasts of Norfolk, Suffolk, and Essex, "with the ocean, this level, in the present case, may be "considered to be the same as the mean height of the "sea."

These observations are fully confirmed by the fact, that in the vicinities of Weymouth, Brighton, Dover, and other places on the coast where the chalk formation abounds, large quantities of fresh water are constantly discharged from the pores of the chalk into the sea.

At Lulworth Cove, a curious natural basin situated about nine miles to the east of Weymouth, a large body of fresh water may be seen, at low tide, constantly running into the sea, through the shingle that covers the coast. Fresh water, issuing in the same manner, may also be traced at other points, not far distant.

A fine spring, issuing from the chalk, near Lulworth Cove, at an elevation of 20 or 25 feet above high-water, turns an overshot water-wheel for grinding corn. Very powerful springs, issuing from the chalk a short distance inland, may also be seen in abundance in other places near Weymouth. The Upway Spring, about four miles north of Weymouth, is thus described in a guide book for that town:—"Behind a semi-circle of poplars, and at "the higher end of the village, is the *Upway Spring*. A "low stone wall, at the foot of the hill, marks its very "retired position. This spring usually rises three feet "above the ground, and appears like boiling water; but "in wet seasons of the year it becomes a large fountain, "rising considerably above the surface of the stream. "This spring is remarkable for the purity and invigorat- "ing properties of its water. It was a favorite spot of

"King George III., who caused a seat to be placed for "himself at the foot of the hill, in full view of the "fountain."

In the neighbourhood of Brighton, the rain is so rapidly absorbed, that no drains or water-courses are required or used, to carry off the heaviest falls, and fresh water at all times may be traced at the bottom of the shingle at low tide, oozing through the beach, and at many places even from the margin of the land, especially on the western side of the town.

Between Folkestone and Dover the same may be observed at various points, and especially in a cutting made by the Railway Company, leading to the Martello Tower Tunnel. Here also along the coast, birds may be noticed drinking fresh water, which issues from the rocks at low tide. There is likewise a celebrated spring, between Dover and Folkestone, called Lydden Spout, which discharges a body of water at an elevation of about 20 feet above high-water, through a fissure in the chalk cliff. This spring is a good example of the impervious character of some of the beds of the chalk formation, the water discharged from it being conducted for a long distance through fissures or openings in this rock.

At Dover the level of the water in many or most of the wells supplying the town varies with the tide. Mr. Watson's well in Limekiln Street, is 13 feet higher at high tide than at low tide, but is never brackish or affected by the sea, so constantly and rapidly is fresh water here discharged from the upland to the coast. This well is only a specimen of the rest, excepting a few in the lower part of the town, which are occasionally brackish during extreme high tides.

The Cornwell station of the Coast Guard is situated on the cliff to the eastward of Dover Castle, about 400 feet above the level of the sea. A zigzag path has been

formed down the face of the cliff to the coast, and all the water required for the domestic use of the Coast Guard station, is fetched from a spring issuing from a rock which is under water at high tide; this spot is known to the sailors of the coast by the name of the Cobler's rock, and water is obtained from it at low tide, and carried up to the station in small casks slung over the back of a donkey, which has been trained to go up and down the zigzag path. During the neap tides, as the sea does not retire far enough to allow the Cobler's rock to be reached, a supply of water for several days' consumption is previously secured.

At St. Margaret's bay, situated between Deal and Dover, a large body of fresh water may be seen issuing from below a reef of rocks, which are only uncovered at low tide.

In the bottom of the well at Dover Castle, which is 315 feet deep, the current of water towards the sea may be distinctly seen. When the well for the supply of the western heights at Dover was first sunk to the depth of low water, the rock proved so dense that no water percolated through, and in consequence, a horizontal gallery was driven at the bottom of the well; after proceeding some distance, a workman observed a small stream of water to follow the withdrawal of his pick-axe; on the next blow this stream was very much increased; and on the third there issued such a rush that the workmen escaped from the well with great difficulty, for the water filled the shaft nearly as fast as they could be drawn up.

Persons practically acquainted with the chalk formation, may perhaps consider the above relation unnecessary, as the enormous amount of fresh water contained in it is well known to them; others, however, may not be so well informed of the circumstance.

APPENDIX O.

THE Brighton Water Company, during a portion of the summer season in 1849, when a large quantity of water was consumed for watering the roads, raised more than a million of gallons per day from a well sunk in the chalk, about 11 feet diameter, with four adits at the bottom, each about 2 yards square and 18 yards long; the adits being about on a level with low-water mark. Since this well was sunk, the fissures in the chalk leading to the well have considerably increased in size, and the well is in consequence capable of yielding much more water than when first made.

The level of the water in this well annually varies about 50 feet, being sometimes as much as 63 feet above high-water mark, and at others only 13 feet above the same datum; it is usually lowest in the months of November or December.

APPENDIX P.

THE well-waters of London, for the most part, contain in solution a very large amount of saline matter, and yet they are preferred by very many persons as a beverage, doubtless owing to the organic matter contained in the water supplied by the Companies.

Professor BRANDE, F.R.S., V.P.C.S., &c., states, in a paper published in the Journal of the Chemical Society for January, 1850, that the

	Grains.
Well in St. Paul's Church Yard contains of solid matter per imperial gallon	75·0
„ Bream's Buildings . . .	115·0
„ St. Giles's, Holborn . . .	105·0
„ St. Martin's, Charing Cross .	95·0
„ Postern Row, Tower . .	88·0

APPENDIX Q.

ABSORPTION OF WATER BY CHALK.

The absorption of water by the upper stratum of chalk is so rapidly effected, that it not only carries down the whole of the rain reaching its surface through a porous soil, but when covered by a retentive clay, it is frequently used to effect the drainage of large areas of land, as shewn in the following extract from *Rees's Cyclopædia*, article "Spring":—

"In Hertfordshire, if a pit be sunk twenty or thirty "feet in depth, in the middle of a field, through the red, "flinty, and impervious clay of the county, into the chalk "below, when the usual quantity of chalk is taken out, "and the pit shaft filled up with the flints which are col- "lected out of the chalk and clay, the top or surface "drainage of this part of the field is much shortened for "ever afterwards *by making principal drains from the "part of the field above the level of the top of the pit termi- "nate therein, and the superabundant moisture will escape "through the flints in the pit shaft to the chalk below.*"

Many other instances might be cited of the absorbent power of the upper chalk being taken advantage of in a similar manner.

APPENDIX R.

The population residing on the water-shed or ground draining into the river Thames above Medmenham or Henley, according to the census of 1841, numbers 535,982 persons; and, calculating the increase at the same ratio as the preceding 10 years, now amounts to 576,565.

The population residing upon the area of ground draining into the Thames above Teddington Locks, calculating the increase from 1841 in the above manner, consists of 839,057 persons.

APPENDIX S.

There being a prevailing notion that the Thames water taken to sea is found, after fermentation, to clear itself and become excellent water for the use of ships' companies, I wrote to Mr. H. Martin, the Engineer of the East and West India Docks, to inquire if there were any foundation for this popular notion, and received the following answer:—

"Engineer's Office,
"East and West India Docks,
"14*th January,* 1850.

"Dear Sir,

"The supply of water for the use of shipping is considered one of the most important subjects connected with dock accommodation; and large sums of money have been expended at this establishment, for the purpose of ascertaining the best means of accomplishing the object, more especially with reference to the quality. Originally the Company obtained the supply from the river Thames, as being the readiest means of procuring the large quantity necessarily required for the vessels resorting to their establishment; and at considerable cost constructed a powerful steam engine, capacious tanks and filter beds, which were made to connect with pipes laid round the dock, to afford a ready and easy distribution to ships lying alongside the quays.

"At the time these plans of supplying water from the river Thames were under investigation, it was discovered, by the experiments then made, that at certain periods of the day, Thames water was wholly unfit for shipping purposes; but that at other times, some of less objectionable quality could be obtained, and such as might probably be fit for shipping uses: of this less inferior kind, after much consideration, it was thought desirable to make a trial,

care being taken that no other than that esteemed the best, should be furnished on any occasion. After the system had been at work some time, numerous complaints were made, that the water furnished by the Company was impure and unfit for use; in some cases the whole had to be thrown overboard, and the vessels were compelled during the voyage, to seek a port where water could be obtained in place of that thrown away. These objections being of a serious nature, the subject was again attentively considered; and the inquiry led to the determination to sacrifice the large outlay already incurred, and wholly abandon the plan of taking the supply from the river. Other plans were then suggested, and partially tried; but after mature investigation, it was resolved to take the water from one of the Water Companies, whose supply was not derived from the Thames, and even this water we now filter before it is put on ship-board. Additional works of an extensive kind had therefore to be constructed, and a large extra annual charge was necessarily incurred for payment of the water thus supplied. I should mention, that the Dock Company never expected to derive any profit from this branch of their business; and when Thames water was used, the charges made by them were fixed at a sum only sufficient to pay the current expenses of raising and delivering: at present the Company are great losers, as the charges originally made are not altered; and the Company have now to pay a large annual cost, as rent, for all the water obtained by them.

"Yours truly,

"H. MARTIN.

"To S. C. Homersham, Esq., C.E."

APPENDIX T.

The following Table shews for several years the depth of rain falling at Greenwich, and at various places situated near to and upon the chalk formation. It is acknowledged by all meteorological authorities, that a greater amount of rain is precipitated upon and near to elevated ground than in lower districts, and if accurate data could be obtained, I have no doubt that in the driest years, at least an average of twenty-six inches of rain in depth per annum, would be shewn to fall upon the area of chalk country to the north and west of Watford :—

Years.	Greenwich Royal Observatory. Rain guage fixed near the ground.	Hastings, Kent.	Dickleborough Norfolk, situated about 120 feet above the level of the sea.	Chesham, Bucks.	Southampton. Surface of rain guage, 9 ft. 7 in. above the ground.	Aylesbury, Bucks.	Hungerford, eastern part of Wiltshire, 320 ft. above mean level of the sea.
	Ins. 10ths.	Ins. 10ths.	Ins. 10ths.	Ins. 10ths.	Ins. 10ths.	Ins. 10ths.	Ins. 10ths.
1838	21·64	26·64					26·26
1839	26·99	34·67					30·37
1840	16·43	25·62	18·86				21·45
1841	33·26	42·15	30·65				33·89
1842	22·57	26·68	24·96				27·52
1843	24·47	30·43	28·37				31·29
1844	24·96	32·40	24·15				21·04
1845	22·34	31·25	26·52				24·08
1846	25·29	35·495	22·33				27·10
1847	17·61	22·36	18·40		Febry. to Decemb.	22·5	19·28
1848	27·94	43·53	32·42	38·41	41·72	34·7	34·07
1849	23·69	32·54	23·88	29·05	32·998	28·2	22·71
Mean	23·93	31·98	25·05	33·73	37·35	28·4	26·58
Lowest	16·43	22·36	18·40	29·05	32·998	22·5	19·28

I am indebted to the kindness of James Glaisher, Esq.; the Rev. Samuel King, Latimer Rectory, near Chesham; John Banks, Esq., Rock House, Hastings; W. H. White, Esq., and John Drew, Esq., Southampton; for the information given in the above Table.

APPENDIX U.

The following is extracted from a paper on "Watering of Farm Fields in Periods of Drought, and for the Distribution of Liquid Manures, by Pumping, and a System of Pipes," by Mr. James Smith, of Deanston, which lately appeared in the *North British Agriculturist*:—

"It has been ascertained by the analysis of drainage-
"water, that a considerable portion of the dung put upon
"land passes off with the superabundant rain-water. I
"therefore propose, that upon every farm there should be
"a pond, or reservoir, to catch and store up the drainage-
"water of the wet season, that it may be thrown upon
"the land in dry periods—thus saving, as far as it is pos-
"sible, the enriching matter which would otherwise be
"lost."

THE END.

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